Biomedical Research 2017; 28 (17): 7412-7418 *ISSN 0970-938X*
www.biomedres.info

Application of cluster airway management to patients with severe inhalation injury.

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Abstract

Objective: To investigate the effect of cluster airway management in patients with severe inhalation injury.

Methods: Sixty-seven patients who suffered from severe inhalation injury and underwent a tracheotomy between June 2013 and June 2016 were selected for this study. The developed cluster airway management program included the airway assessment and emergency treatment, asphyxia detection and treatment, body position management, sputum suction care, subglottic suction, airway humidification, airbag management, tracheal tube care, tracheotomy site care, thoracic lung care, oral care, management of respiratory tracts, and medical environmental infections control. Observation group consisted of 35 patients hospitalized between January 2015 and June 2016 and treated with implementation of the cluster airway management. Control group consisted of 32 patients hospitalized between June 2014 and December 2015 and not treated with the cluster airway management. The evaluation of the two groups of patients included daily arterial blood gases (ABG) analysis indicators (pH, PO_2, PCO_2, Lac) and oxygenation index. Blood oxygen saturation (SpO_2) was measured on the days 1, 3, 6, 9, and 12 of hospitalization.

Results: There were significant differences in the levels of pH, PO_2, Lac and SpO_2 between the two groups on the days 6 and 9 of hospitalization (P<0.05* or P<0.01). The level of PCO_2 was significantly different between the two groups on the days 3, 6 and 9 of hospitalization (P<0.01**). There were statistical differences in the oxygenation index between the two groups on the days 9 and 12 of hospitalization (P<0.05* or P<0.01**). There were significant differences in patients' sputum characteristics between the two groups during the first, second and third weeks of hospitalization (P<0.01**).**

Conclusion: Application of cluster airway management can effectively improve the oxygenation status of patients and the viciousness of patient's sputum affected by an inhalation injury, and reduces the incidence rate of pulmonary infections.

Keywords: Inhalation injury, Cluster airway management, Oxygenation status, Pulmonary infections.

Accepted on July 18, 2017

Introduction

Inhalation injury has high incidence and is associated with high mortality, especially in an enclosed environment where smoke-induced inhalation injury is one of the most common causes of death [1]. Shirani et al reported that the severity of an inhalation injury is directly proportionate to the area of the burn [2]. Mortality of patients with an inhalation injury alone was expected to increase by a maximum of 20%, and by 60% with both inhalation injury and pneumonia. A meta-analysis on prognostic factors in patients with both cutaneous and inhalation injuries indicated that mortality increased significantly with inhalation injuries [3]. While many strategies have been developed to manage cutaneous burn injuries, few logical diagnostic strategies for patients with inhalation injuries exist and almost all treatment is supportive. It is now well known that rapid diagnosis and treatment are key when it comes to inhalational burns, as acute complications, which sometimes go unnoticed, are the reason behind long term sequels [2] and the high mortality rate seen with this type of injury. Over the last three decades, survival rates of patients with burn injuries have steadily increased due to new treatment modalities, as well as a decrease in the severity of burns [4-7]. Studies to elucidate the systemic repercussions of inhalational injury have suggested specific antidotes, in addition to the general life-sustaining measures usually used [2,5]. Despite important advances in the care of patients with inhalation injury, which continues to be largely supportive, morbidity and mortality remain high [1]. Inhalation injury can feature supraglottic thermal injury, chemical irritation of the respiratory tract, systemic toxicity due to agents such as carbon monoxide (CO) and cyanide, or a combination of these insults. The resultant inflammatory response may cause higher fluid resuscitation volumes, progressive pulmonary dysfunction, prolonged ventilator days, increased risk of pneumonia, and acute respiratory distress syndrome (ARDS). A severe inhalation injury often requires a prophylactic tracheotomy aimed at establishing an artificial airway to support and improve a patient's ventilation. The specific artificial airway cluster nursing strategies are based on actual situation of patients. They may include an implementation of a series of artificial airway therapies and nursing procedures based on patient's symptoms to prevent the occurrence of complications [2] and to improve the quality of care and treatment of patients. At present, the cluster airway management is mainly used in an Intensive Care Unit (ICU) ward to establish the artificial airway or mechanical ventilation of patient, but there are very few studies on the airway management in inhalation injury. Since June 2014, our Department applied cluster airway management to patients with severe inhalation injuries and has achieved rather good results, as discussed in this article.

Materials and Methods

Clinical data

Before starting, research study, the permission and approval was taken from the Ethical and Research board committee. The informed consent form was also obtained from each and every patient. The total sample size was comprised of 67 patients reported to our department. Then the total sample size had been divided into further two subgroups. The observational group comprised of 32 patients who suffered from a severe inhalation injury and were hospitalized in our Department during the period between June 2013 and December 2014 and was treated with the cluster airway management.

The control group was comprised of 35 patients with severe inhalation injury hospitalized in our Department between January 2015 and June and have not received the cluster airway management treatment. The exclusion criteria were as follows: 1) Age younger than 18 years or older than 60 years; 2) History of heart pulmonary diseases; 3) Lack of standardized rehydration and standardized treatment after injury; 4) Burn area larger than 30% of the body; 5) Not meeting the criteria of severe inhalation injury upon assessment [3]. The total of 67 patients in both groups included 45 males and 22 females aged between 20 to 58 years with the burn area ranging between 1% and 30% of body surface. The composition of two groups was not significantly different in respect to patients' age, gender, location of burns and burn area (P>0.05) (Table 1).

Table 1. *Characteristics of patient in two groups.*

Group	Number of Cases	Age (Years)	Gender		Burn Area %	Burn Site	
			Men	Women	Face & Neck	Other Parts	
Control Group	35	34.6 ± 10.3	25	10	21.9 ± 8.7	28	7
Observation Group	32	32.7 ± 11.9	24	8	18.5 ± 9.4	26	6
t/ X^2 Value		0.700	0.109		1.538	0.0167	
P-Value		>0.05	>0.05		>0.05	>0.05	

Methods

Design of the cluster airway management program: The cluster airway management program was developed through reviewing the available literature and guidelines. Specific components of the program are outlined below.

Assessment of airway and emergency treatment: After admission, a patient should be checked for the followings: the injury site(s), the area of the face and neck wounds, the depth of wounds and the existence of ring wound [4], the degree of swelling of face, neck and lips, the swallowing function and the coughing sputum function. Auscultations should be used to examine respiratory sounds, as patient's rales and wheezing provide important information about the pulmonary function of lungs. The respiratory rate and SpO_2, blood gases of PaO_2, $PaCO_2$, pH, and Lac values of patient should be monitored to assess the patient's oxygenation level and acid-base balance. The patient's airway must be opened to effectively remove any respiratory secretions, and the patient must be given a mask of high-flow oxygen (15 L/min) [5]. The artificial airway should be chosen and prepared according to the information obtained during the patient's assessment, and the auxiliary ventilation items and equipment should be prepared.

Diagnostics and treatment of asphyxia: Asphyxia can develop due to early stage airway edema and mucosal shedding caused by airway obstruction. A nurse should be alert to patient's coughs, changing position, sudden breathing difficulty and wheezing. The patient should be effectively cleaned from airway secretions and any foreign bodies [4]. At bedside, the suction equipment and the fiber bronchoscopy equipment should be ready for using. When patient shows any of the above mentioned symptoms, he/she should be encouraged and be stimulated to cough hardly. When necessary, fiber bronchoscope should be used to remove a foreign body. The latter procedure requires participation of a physician.

Body position management of patient: Patient's body should be keep elevated at 30°-45° in the bed, or at semi-recumbent position, if it is possible. The patient's position has to be changed every 3 h, if the patient's conditions allow doing so. A bed with a rollover function can be used [6-8].

Care for sputum suction: The sputum suction should be performed when one of the following aspiration problems are detected: rough breathing sounds or lung auscultation with phlegm, visible secretion in the artificial airway, alarm of high pressure on ventilator. For an adult patient, the diameter of the suction tube should be less than 50% of the diameter of tracheal intubation used. Saline infusion should not be applied before the sputum suction. The negative pressure of suction should be kept between 80~120 mmHg, as high viscosity of sputum may increase the negative pressure. Pure oxygen should be provided for 30-60 s before and after the sputum suction. Each suction time should be less than15 s. A closed suction tube should be used for the procedure. Oral suction should be also given before rolling over the patient. Attention should be paid to the nature of sputum, as presence of mucosa fragments may point to potential mucosa suffocation [6-9].

Subglottic suction: Subglottic suction should be applied to a patient when rolling over and adjustment of airbag pressure are needed, and in some other specific situations. Continued or intermittent subglottic suction with a pressure of 70 mmHg should be provided [6-9].

Airway humidification: Active humidification should be used in patients on non-invasive and invasive ventilation. Heated humidifier should be used for airway humidification and for maintaining the humidity level of inhaled gas at 33 to 44 mg/L. The gas temperature at a "Y" -shaped end should be maintained at 34-41°C, with 100% relative humidity. In patient who received a low tidal volume, the heat and moisture exchanger for airway humidification should not be applied. To evaluate the effect of airway humidification in a timely manner, a sputum status should be maintained at II degree according to the viscosity of sputum. Reasonable arrangements for aerosol use could be done based on the results of lung auscultation and the status of sputum. Atomization dose and frequency can be increased with mechanical ventilation. Atomizer should be rinsed with water and wiped with 75% ethanol after the use, kept in a sterile tray and replaced every 72 h. Heating humidifier in mechanical ventilation patients should be exchanged every 5-7 days [9-12].

Airbag management: Conical airbag made of polyurethane should be used. The pressure of airbag should be maintained at 25-30 cm H_2O. The airbag pressure should be 2 cm H_2O higher than the ideal value. In the case of an unconventional application of the minimum closure technology to inflate the airbag, the air bag pressure cannot be measured, and therefore the minimum closure technology inflation can be used only temporarily [13].

Care of silver tracheotomy inner sleeve: Silver tracheotomy inner sleeve should be sterilized by boiling. The inner sleeve should be removed, boiled for 30 min, and wiped off from any adhesions or sputum on the inner wall with sterile gauze, followed by boiling for additional 5 min, rinsing with sterile water and drying by air. Inner sleeve made of plastic can be soaked in 75% alcohol for 30 min with a thorough cleaning, and then rinsed with sterile water and dried by air. The inner sleeve should be re-installed within an hour after sterilization in order to avoid the airway blockage by sticky mucus. The inner sleeve must be sterilized after each tracheotomy dressing changing. In cases when too much secretion is produced or the secretion is too viscous, the cleaning and sterilization should be done more frequently.

Care of tracheotomy: The number of tracheotomy dressing changes should be determined according to the wound characteristics. Attention should be paid to certain specific characteristics of the wound such as the color of tracheotomy dressing, the incision odor, the presence or absence of the bleeding and sputum leaks etc. The elastic band of tracheal tube should be of appropriate tightness, since the edema which occurs at the burned skin and the burned airway mucosal reaches its peak at 6-12 hours after the injury and gradually dissipates 48 h post-injury [14]. Therefore, during the first week after injury, the tightness of an elastic band of tracheal tube should be adjusted based on the state of edema and the degree of edema subsiding.

Thoracic lung care: We encouraged patients to cough, or applied buckling on the back, shaking and other mechanical means to expedite sputum for no less than 10 min every 3 h to promote sputum discharging. For patient with respiratory muscle weakness or invalid cough, a cough aid could be used. If a patient did not tolerate the turning over and knocking on the back to expectorate, the cough aid can be used independently or combined with an expectoration apparatus whose percussion frequency is 10-35 cps. Based on the individual's situation, a lower frequency of no more than 25cps can be applied initially, 1-4 times a day for 5-10 min at each side. The aspiratory pressure setting of expectoration machine should be no higher than 20 cm H_2O to prevent baro-trauma. During expectoration and suction of sputum, the patient should be closely monitored for any abnormal vital signs and breathing difficulties. We encouraged patients to take deep breaths to exercise the lungs function [15,16].

Oral care: Oral care is utmost important in these kind of the cases The patients should be advised to have the brushing of the teeth properly 2 times day after the food. Those patients who is having the physical disability and not able to do the brushing, in these cases chemical disinfectant like cholre-hexidine 0.2% or 0.12% had been used For the brushing, modified bass technique for the brushing must be adopted by the patients. A syringe with saline or oral care solution can be used to wash both sides of the oral cavity. Simultaneously, the vacuum can used to suck out the washing liquid from the opposite side of the oral cavity. Once the oral care procedure for cleaning is conducted, a final wash for the various oral parts should be performed [17-19].

Breathing pipeline management: A disposable heated and humidified pipeline should be used whenever possible. The pipeline position must be maintained lower than the position of the airway to avoid accumulation of the condensed water flowing back into the patient's lungs. The water bottle to collect condensate must be placed at the lowest position of a ventilator pipeline and should be regularly emptied. The ventilator piping should not be routinely replaced. In patient whose sputum culture tests indicate the colonization by any resistant bacteria or infection, the ventilator piping must be replaced every 48 h. If any contamination or damage occurs to a part of ventilator piping, then the ventilator piping must be replaced.

Control of medical environmental infection: Hand cleanliness must be maintained at all time. The nurse hands must be washed before and after the contact with a patient, before an invasive operation, after the contact with mucous membranes of a patient and his/her respiratory secretions, after the contact with contaminated items, etc. A weekly hand hygiene spot check should be performed. An effective isolation and replacement of the medical staff's contaminated clothing must be done as soon as possible to keep the environment clean [20-22].

Implementation of the cluster airway management program: The airway management team received standardized training and assessment for general nursing staffs on the cluster airway management program. The training aimed to ensure that the general nursing staffs works according to the unified airway management standards when performing the implementation of the airway care management.

Evaluation methods: Two groups of patients were evaluated statistically on the following three parameters.

(1) Daily arterial blood gases (ABG) test parameters on hospitalization days 1, 3, 6, 9, and 12, which included pH, PaO_2, $PaCO_2$, Lac, oxygenation index (PaO_2/FiO_2), and blood oxygen saturation (SpO_2).

(2) Sputum viscosity status at weeks 1, 2 and 3 of hospitalization. The sputum was graded according to its viscosity as follows. I degree: liquid sputum, the appearance of sputum is similar to rice broth or foam, no sputum retention on the suction pipe wall. II degree: the appearance of sputum is more viscous, a small amount of sputum retained on the suction tube wall, but it can be easily rinsed off. III degree: the appearance of sputum is very sticky, it often has yellow color, the suction tube could often collapse due to large negative pressure, large amounts of sputum retained on the suction pipe wall and it is difficult to rinse off.

(3) The positive results of sputum culture test in weeks 1, 2 and 3 of hospitalization.

Statistical methods

All data were statistically analyzed using SPSS20.0 software. The measurement data were compared with t test, while the counting data were compared with χ^2 test. P value smaller than 0.05* indicated a statistical difference; P smaller than 0.01** indicated a significant difference.

Results

There were statistical differences between the two groups of patients on the pH and PO_2 values on the 6th day and the 9th day of hospitalization (P<0.05* or P<0.01**). The PCO_2 values of the two groups on the days 3, 6 and 9 of hospitalization showed significant differences (P<0.01**). The values of Lac and SpO_2 in the two groups on the days 6 and 9 of hospitalization were significantly different (P<0.01**). The oxygenation index values in the two groups on the 9th day and the 12th day of hospitalization showed statistical differences (P<0.05** or P<0.01*) (Table 2).

Table 2. *Comparisons of blood gases analysis indicators between the two groups of patients.*

Test Time	Group	Cases	pHValue	PO_2 (mmHg)	PCO_2 (mmHg)	Lac	SpO_2 (%)	Oxidation index (kPa)
Day 1	Control Group	35	7.28 ± 0.22	75.5 ± 20.7	49.6 ± 4.3	2.21 ± 0.43	91.0 ± 3.4	30.7 ± 3.4
	Observation group	32	7.31 ± 0.18	79.7 ± 19.8	48.5 ± 5.7	2.10 ± 0.39	92.0 ± 3.3	31.5 ± 3.6
Day 3	Control Group	35	7.33 ± 0.23	85.4 ± 18.5	50.4 ± 6.3	2.01 ± 0.41	92.1 ± 2.9	35.1 ± 4.6
	Observation Group	32	7.37 ± 0.27	87.1 ± 16.9	44.1 ± 5.6**	2.04 ± 0.36	93.5 ± 3.2	34.7 ± 5.2
Day 6	Control Group	35	7.32 ± 0.14	86.6 ± 20.8	48.2 ± 5.9	1.94 ± 0.33	93.4 ± 2.8	36.2 ± 4.7
	Observation Group	32	7.40 ± 0.13*	108.5 ± 21.6**	41.7 ± 6.5**	1.27 ± 0.27**	97.3 ± 2.0**	43.5 ± 4.8
Day 9	Control Group	35	7.33 ± 0.07	94.7 ± 17.5	45.8 ± 4.7	1.38 ± 0.26	97.5 ± 1.6	40.5 ± 5.3
	Observation Group	32	7.43 ± 0.04**	116.7 ± 16.3**	40.7 ± 5.3**	1.09 ± 0.35**	99.5 ± 1.5**	46.4 ± 5.9**
Day 12	Control Group	35	7.41 ± 0.10	112.7 ± 16.5	44.5 ± 5.1	0.94 ± 0.29	99.3 ± 0.5	47.8 ± 5.8

	Observation Group	32	7.40 ± 0.06	113.7 ± 14.9	43.8 ± 4.8	0.87 ± 0.21	99.5 ± 0.7	50.7 ± 5.4*
t1 Value			0.608	0.847	0.959	1.093	0.819	0.935
P1 Value			>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
t2 Value			0.650	0.392	4.274	0.317	1.879	0.222
P1 Value			>0.05	>0.05	<0.001	>0.05	>0.05	>0.05
t3Value			2.424	4.227	4.291	9.054	6.510	1.161
P3Value			<0.05	<0.001	<0.001	<0.001	<0.001	>0.05
t4Value			7.092	5.311	4.134	3.877	5.267	4.312
P4Value			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
t5Value			0.492	0.259	0.596	1.271	1.355	2.112
P5Value			>0.05	>0.05	>0.05	>0.05	>0.05	<0.05
Note: Compared with the control group, *P<0.05, **P<0.01.								

In context to sputum viscosity, the comparison had been done between the observational group and the control group in week 1st, 2nd and 3rd week of hospitalization. The results revealed the statistically significant p value of less than 0.01 in the week 2nd and 3rd and showing that the sputum viscosity was at higher side in the observational group in comparison to control group. The findings recalled the same observation in the 1st week of hospitalization but significant pm value of less than 0.05 (Table 3).

Table 3. *Comparisons of the two groups of patients on the sputum status.*

Test Time	Group	Cases	Sputum Viscosity			X^2 Value	P Value
			Degree I	Degree II	Degree III		
The 1st Week	Control Group	35	4	22	9	5.233	<0.05*
	Observation Group	32	11	16	5		
The 2nd Week	Control Group	35	9	19	7	7.845	<0.01**
	Observation Group	32	19	10	3		
The 3rd Week	Control Group	35	12	16	7	15.109	<0.01**
	Observation Group	32	26	5	1		

There were significant differences in the positive results of the sputum culture tests between the two groups after the first, the second and the third weeks of hospitalization (P<0.01** or P<0.05*) (Table 4).

Table 4. *Comparisons of the positive results of the sputum culture tests between two groups of patients.*

Test Time	Group	Cases	Sputum Culture Test Positive	X^2 Value	P Value
The First Week	Control Group	35	14 (40.00)	6.434	<0.05*
	Observation Group	32	4 (12.50)		
The Second Week	Control Group	35	17 (48.57)	8.227	<0.01**
	Observation Group	32	5 (15.62)		
The Third Week	Control Group	35	24 (68.57)	10.94	<0.01**
	Observation Group	32	9 (28.12)		

Discussion

Inhalation injury associated with infection and shock is one of the major causes of death in the burn injury patients [23]. Studies have shown that burn injury combined with a moderate or severe inhalation injury doubles the mortality rate [24]. In addition, respiratory complications in burn patients, such as laryngeal edema, acute respiratory distress syndrome (ARDS), pulmonary infection and ventilator associated pneumonia (VAP) cause respiratory insufficiency often leading to death. Therefore, the proper care of airways in such patients becomes particularly important.

As the data in Table 2 show, the SpO_2, the blood gases analysis indicators, and the oxygenation index in the observation group were better compared to the control group, thus demonstrating that cluster airway management improves patient's oxygenation. The adequate oxygenation is achieved through the improvement of both ventilation and gaseous exchange function. It requires opening the airway, to supply oxygen effectively, to reduce the airway mucosal edema, to avoid the airway obstruction, and to promote the elimination of sputum while taking care of the patient. A severe inhalation injury lesion could reach to bronchi, bronchioles, or even alveoli. A bronchial spasm, a small airway obstruction and a pulmonary edema could lead to rapid onset of respiratory distress and hypoxemia. Upper respiratory tract obstruction and airway mucosal edema, as well as necrotic loss can cause dyspnea or even suffocation in a patient. In order to improve patient's ventilation, the program we developed requires to immediately open patient's airway upon admission, provide high concentration of oxygen, reduce head edema and promote sputum drainage, while keeping patient on elevated bed. Several procedures can be performed to promote sputum drainage, including frequent change of patient's position, adequate thoracic and lung care and effective suction of sputum. Burn injury weakens the airways ability to regulate its temperature and humidity due to the loss of exudation at the site of wound. High temperature environment and establishment of artificial airway result in the formation of sticky airway secretions and dry scabs. Selecting a suitable humidifier for active humidification, maintaining the sputum at II degree and promptly paying attention to the indications of sputum suction can ensure the effective expectoration by the patient and help to avoid the formation of sputum scabs. Comparison of the sputum viscosity in the two groups (Table 3) shows that application of the cluster airway management has effectively improved the sputum viscosity in the observation group, prevented the formation of sputum scabs and promoting expectoration.

Various authors have recommended the cluster management in cases of children too. The authors concluded that mechanical ventilation, one of the mainstays of supportive therapy for child patients with lower respiratory tract burns, was the primary indication for PICU admission and was necessary in 42% (n=14) of all study patients. Infection remains a well-documented risk for burn patients. During PICU admission, infections were investigated for in most patients, but there was no routine screening in the absence of clinical signs. It was noted that scald injury patients had a significantly higher proportion of positive cultures. Ingestion patients had no positive cultures but were tested far less. The higher risk of infection in scald injury patients raises the question of whether scald injury patients being mechanically ventilated have a higher risk of infection.

Burn injury is also a susceptibility factor in the development of ventilator associated pneumonia (VAP) in 10-20% of burn patients with inhalation injury. The larger is the burn area, the higher is the incidence rates of VAP [25]. Table 4 shows that the incidence of positive results in the secretion culture test in the observation group was lower compared to the control group after three weeks of hospitalization. Thus, the application of cluster airway management program effectively reduced the incidence rate of lung infections. Bed elevation to 30-45° (semi-lying position) can be effective in preventing aspiration and thus contributes to reduction of VAP incidence [26]. In addition, improper airbag management, oral care and ventilator pipeline care are also known to be the contributing factors to the development of VAP. If an airbag pressure is insufficient, subglottic sediment could enter the lower respiratory tract along the space between the airbag and the airway causing a pulmonary infection or VAP [27,28]. A dental plaque is also a risk factor for a VAP. Halmand pointed out that oral care is the most important part of mechanical intervention in preventing the bacterial implantation [17]. The ventilator's external pipeline could be a point bacterial colonization, along with the extended mechanical ventilation system [29]. Published meta-analysis data demonstrated that periodic replacement of ventilator tubing is associated with an increased incidence of ventilator-associated pneumonia compared to no replacements [30]. Therefore, our protocol required routine monitoring of the airbag pressure and intermittent or sustained subglottic suction, while oral care and ventilator piping care programs were also applied.

Conclusion

This study focused on the pathologic features of patients with severe inhalation injuries and aimed at reducing the airway edema, preventing of asphyxia, promoting sputum discharge, preventing the development of VAP and facilitating the airway management. Through reviewing the available literature and considering the typical symptoms of the patients, this study summarized 13 aspects of the airway cluster management and provided clinical nurses with guidance for proper airway care. Various aspects of cluster management of airway were emphasized at every procedure during the practical implementation of this airway management program, requiring a strict implementation and compliance by all nursing staff. Effective implementation of each procedure can ensure continuous improvement of the airway management in patients with severe inhalatory injuries.

Acknowledgement

This work was supported by the Natural Science Foundation of Jilin Province (No.20160101141JC).

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